Height Maps, Noise, Erosion and Vegetation

Overview

- Height maps
- Noise algorithms
- Erosion Algorithm
- Vegetation Modelling

Height Map

- When we read this grey-scale image in, each pixel represents a vertex.
- We can hence use an image to store the heights (y values) for our terrain mesh.
  - For example:

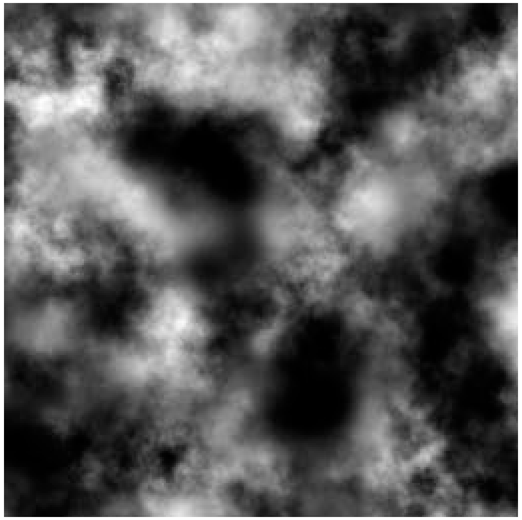


Fig. 1: Example height map with height displayed as brightness.

Heightmap

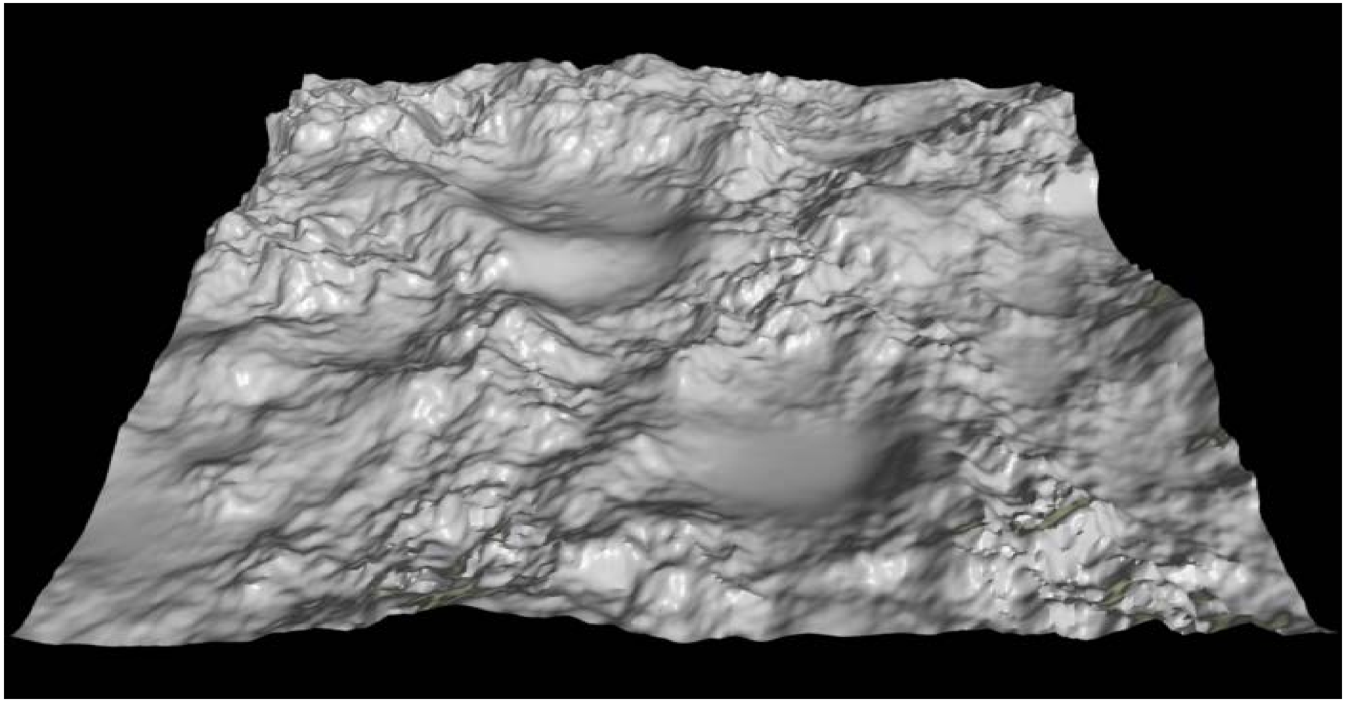


Fig. 2: Height map from Fig.1 converted into a 3D mesh.

Tools

- Height Map continued…
  - 256 x 256 pixels
  - Grey scale:
    - Every pixel has a value from 0 to 255.
    - R,G,B components are all equal.
- Tools
  - Terragen
    - Freeware
    - Can be used to generate height maps.
    - http://www.planetside.co.uk/
  - Photoshop
    - We can easily create our own…

Tools continued

- Bryce http://www.thebest3d.com/bryce/index.html
- Dark Tree http://www.darksim.com/

These tools have many procedural algorithms for generating height-maps and also have built-in height-map editors

Heightmap Generation

- After finishing drawing the heightmap,it needs to be saved in an 8-bit RAW file.
- RAW files simply contain the bytes of the image one after another
- This makes it easy to read the image into the program
- If any software asks to save the RAW file with a header ,specify no header

Heightmap Smoothing

- One of the problems of using an 8-bit heightmap is that it means we can only represent 256 discrete height steps .
- The truncation creates a “rougher” terrain than what may have been intended
- Once we truncate , we cannot recover the original height values but we can smooth the values

Heightmap Smoothing

- So we load the height-map into memory by reading raw bytes
- We copy the byte array into float array so that we have a floating-point precision
- Then we apply a filter to the floating-point heightmap
- This helps to smooth the heightmap out

i-1,j-1	**i-1,j**	**i-1,j+1**
i,j-1	i,j	i,j+1
i+1,j-1	i+1,j	i+1,j+1

Noise

Noise

- In the everyday world, noise is a naturally occurring nuisance that is generally covered up as much as possible
- However, in the field of Computer Science, especially 3D modelling, noise has become increasingly useful
- Irregular bumps and nicks make 3D models look much more realistic, but are difficult and time consuming to make by hand
- Noise algorithms create pseudo-random textures quickly with little or no interaction required from the user.

Use of Noise in Games

- In games, noise algorithms are used to generate landscapes
- Generation of these landscapes often doesn’t stop with noise, often erosion, vegetation, and water models are applied to increase realism

Types of Noise Algorithms

- Mid-point displacement
- Diamond-square
- Value noise
- Perlin noise
- Simplex noise
- Cell/Whorley noise
- Voronoi noise
- Alligator noise
- Space –convolution noise

Basic noise algorithms

- Mid-point displacement
- Diamond Square noise
- Perlin noise

Mid-point displacement algorithm

- The Mid Point Displacement, aka the Plasma Algorithm, is a subdivision algorithm
- The terrain is built iteratively, in each iteration the level of detail increases
- This algorithm was conceived to generate square terrains with dimensions (2^n + 1) x (2^n+1) where *n* stands for the number of iterations

In 1 Dimension

```
Start with a single horizontal line segment.
   Repeat for a sufficiently large number of times
      {
         Repeat over each line segment in the scene
            {
               Find the midpoint of the line segment.
               Displace the midpoint in Y by a random amount.
               Reduce the range for random numbers.
            }
      }
```

In 1 Dimension

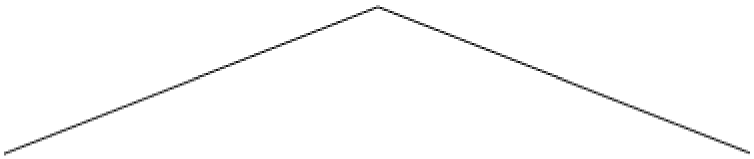


Fig 2 First Iteration

Fig 3 Second Iteration

Fig 4 Third Iteration

Fig 5 Final Iteration

Diamond –square algorithm

- This is midpoint-displacement method in 2-dimension
- Assign a height value to each corner of the rectangle
- Divide the rectangle into 4 sub rectangles, and let their height values be the mean values of the corners of the parent rectangle.
- When computing the middle height, one should add a small error that depends on the size of the rectangle (the standard is to let the error be proportional to the size of the rectangle and some constant.
- The constant controls the "roughness" of the fractal
- A bigger constant results in more valleys and mountains.
- Iterate and subdivide each rectangle into smaller ones.

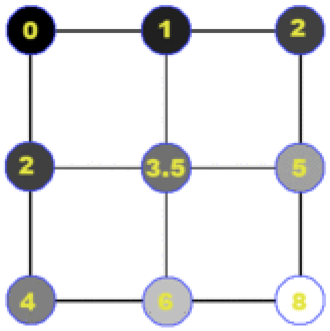
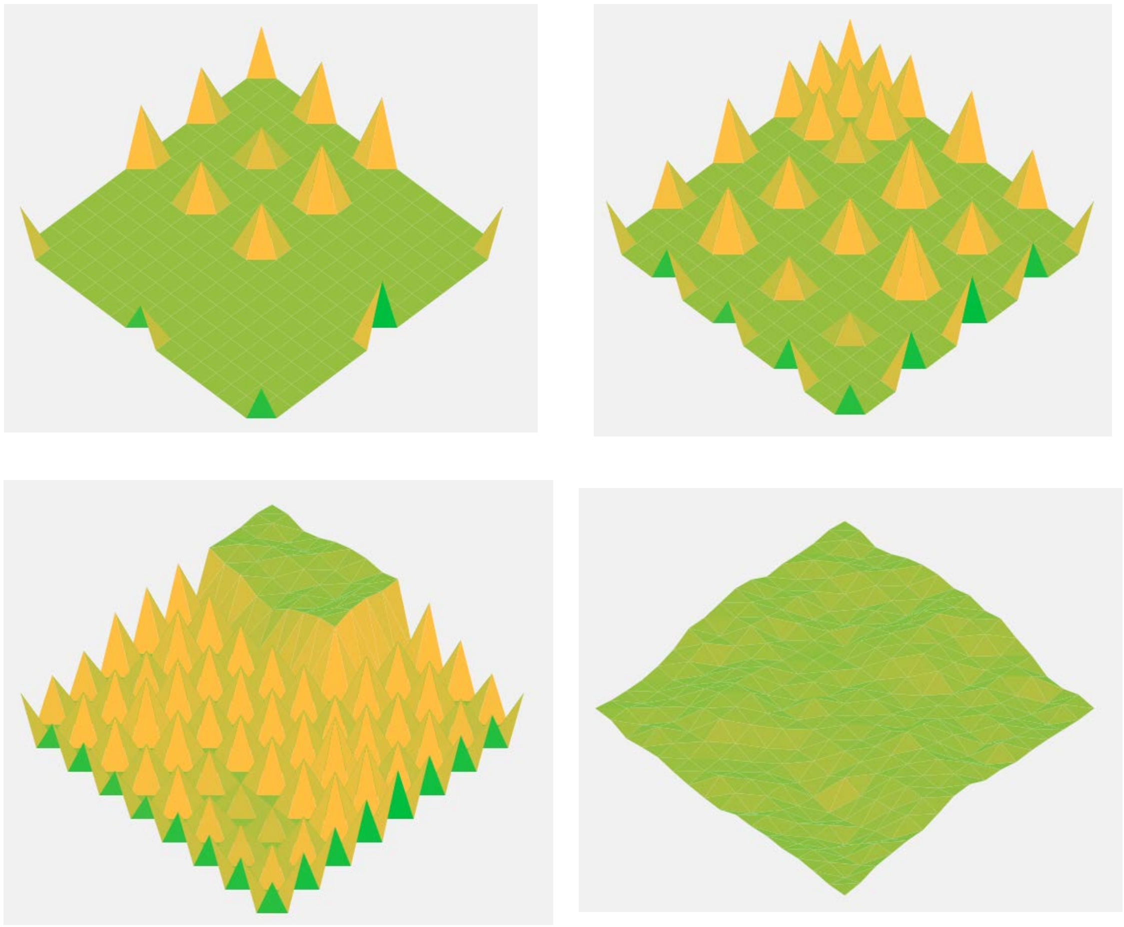
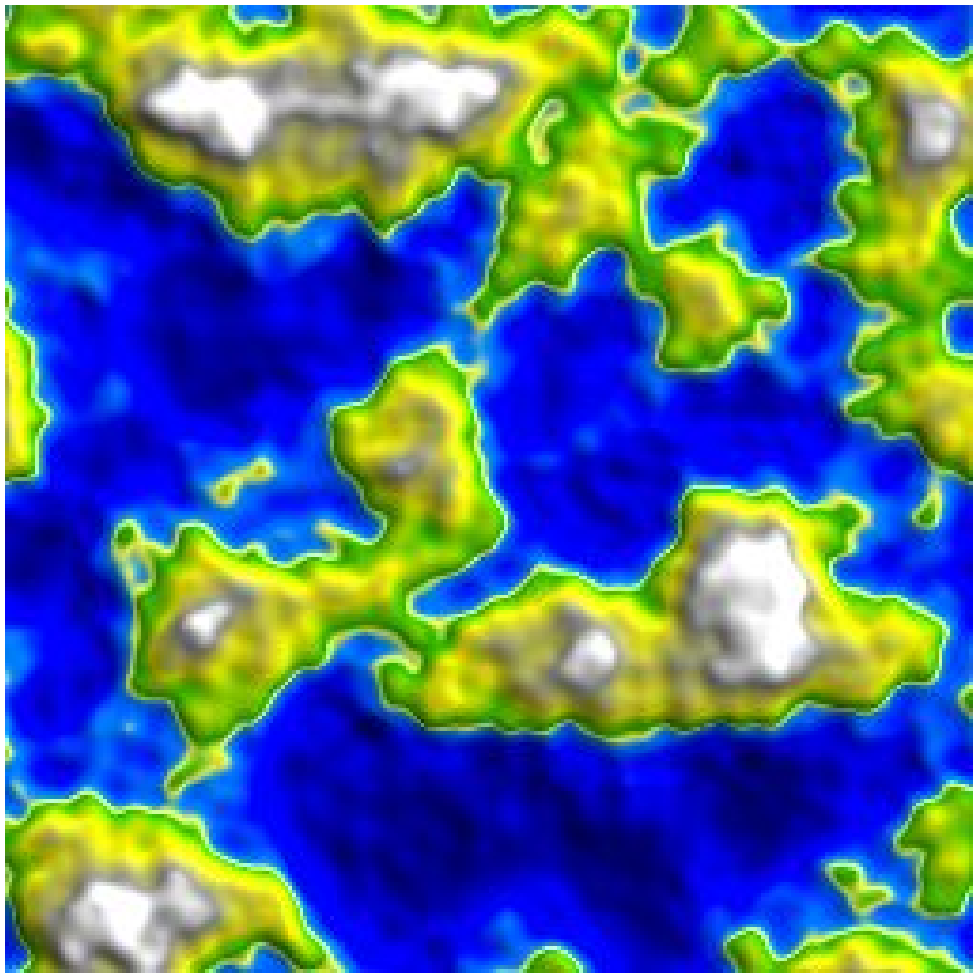


Fig 6 Diamond square algorithm

Diamond –square



Perlin Noise



Perlin Noise

- Perlin Noise is an extremely powerful algorithm that is used often in procedural content generation
- The man who created it, Ken Perlin, won an academy award for the original implementation
- In game development, Perlin Noise can be used for any sort of wave-like, undulating material or texture.
- For example, it could be used for procedural terrain, fire effects, water, and clouds

Process

- Generate Noise
  - For each point in width and height of texture
  - Generate random number
  - Smoothen the value
  - Interpolate
- Apply perlin noise algorithm per point.
- Get a gray scale value per point similar to height map.

Perlin Noise

- Noise Function
  - A noise function is essentially a seeded number generator

- Smooth Noise

```
function SmoothNoise_2D(x, y)

  corners = ( Noise(x-1, y-1)+Noise(x+1, y-1)+Noise(x-1, y+1)+Noise(x+1, y+1) ) / 16
  sides   = ( Noise(x-1, y)  +Noise(x+1, y)  +Noise(x, y-1)  +Noise(x, y+1) ) /  8
  center  =  Noise(x, y) / 4
  return corners + sides + center
  end function
```

Perlin Noise

- Interpolation – Can be linear, cubic, cosine

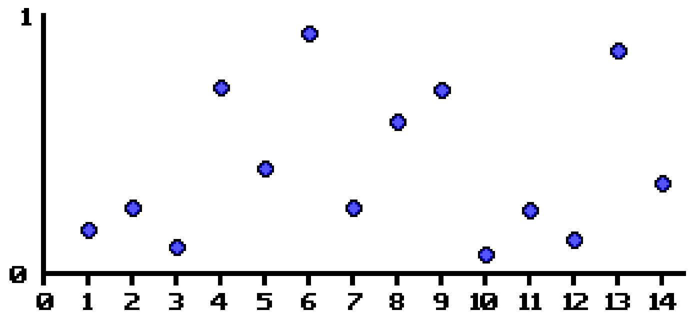


Fig 7 Random numbers plotted

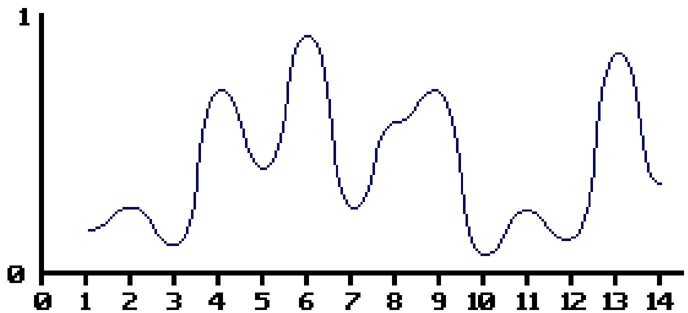


Fig 8 Interpolation

Perlin Noise

- function **Linear_Interpolate**(**a**, **b**, **x**)
  return **a***(**1**-**x**) + **b***x**
  end of function
- function **Cosine_Interpolate**(**a**, **b**, **x**)
  ft = **x** * **3.1415927; f** = (**1** - cos(**ft**)) * **.5**
  return **a***(**1**-**f**) + **b***f
  end of function
- function **Cubic_Interpolate**(**v0**, **v1**, **v2**, **v3**,**x**)
  P = (**v3** - **v2**) - (**v0** - **v1**)
  Q = (**v0** - **v1**) - **P**
  R = **v2** - **v0**
  S = **v1**
  return $Px^3 + Qx^2 + Rx + S$
  end of function

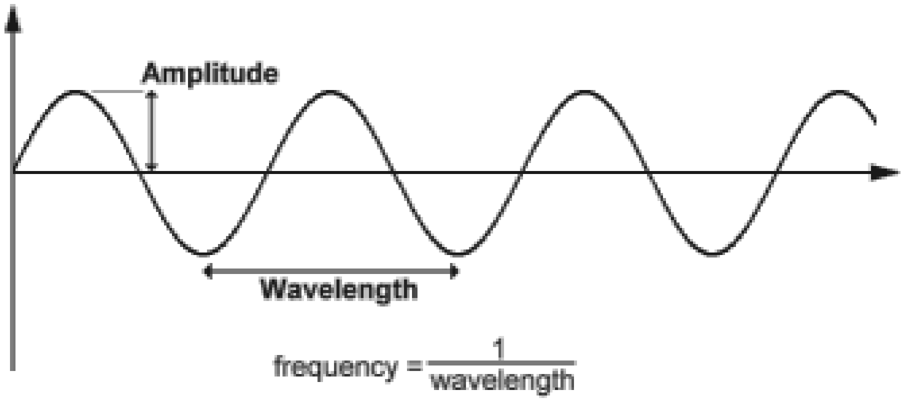
Terminologies

- Amplitude

  The maximum extent of a vibration or oscillation, measured from the position of equilibrium.

- Frequency

  The distance between successive crests of a wave, esp. points in a sound wave or electromagnetic wave



MEDIA DESIGN SCHOOL GAME DEV

Terminologies

- Persistence
  - frequency = 2^i
  - amplitude = $persistence^i$
- **i** is the **i**th noise function being added for each octave
- I might range from 0 to 8

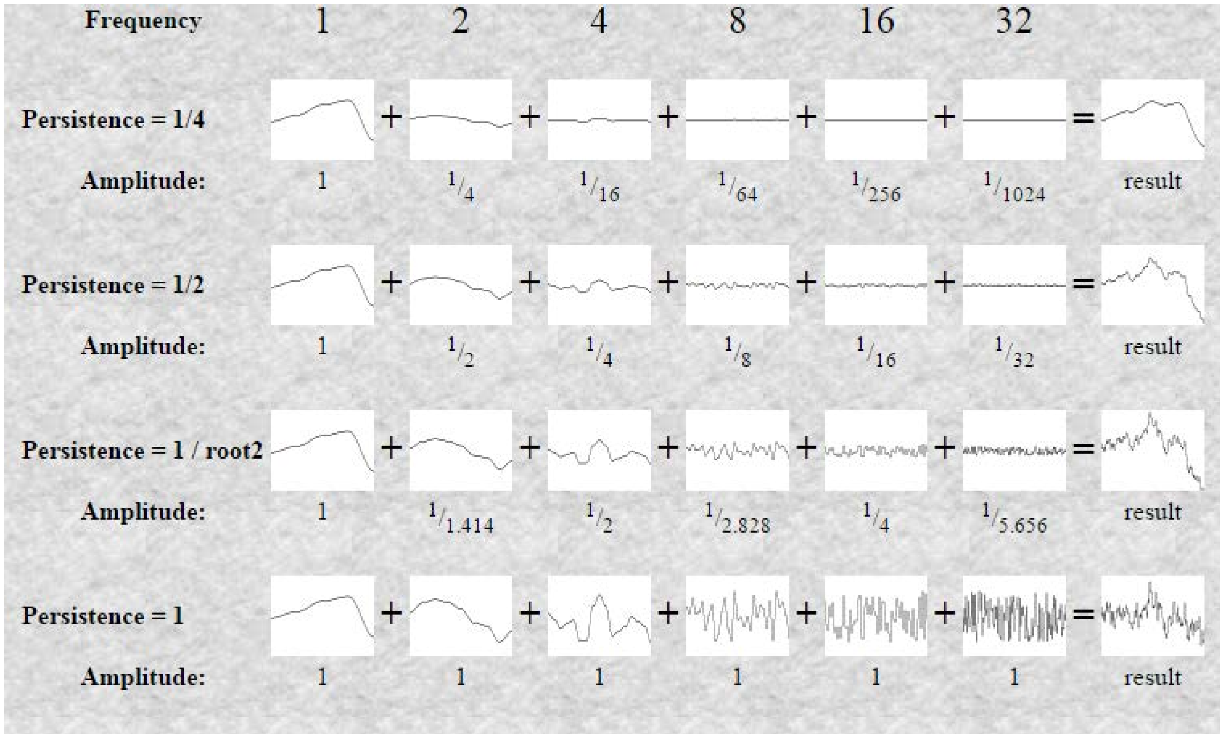
- Octaves

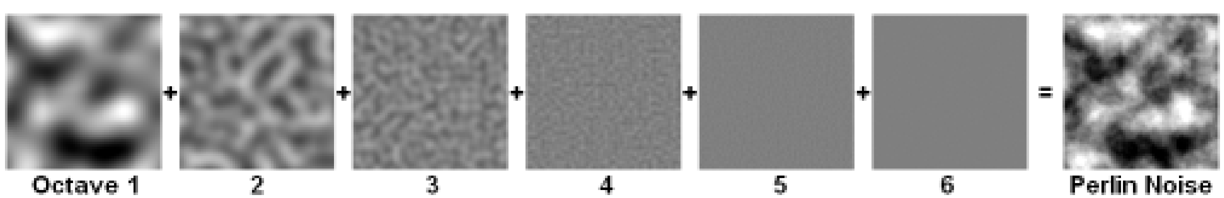
Each successive noise function you add is known as an octave

Total Noise Per Point

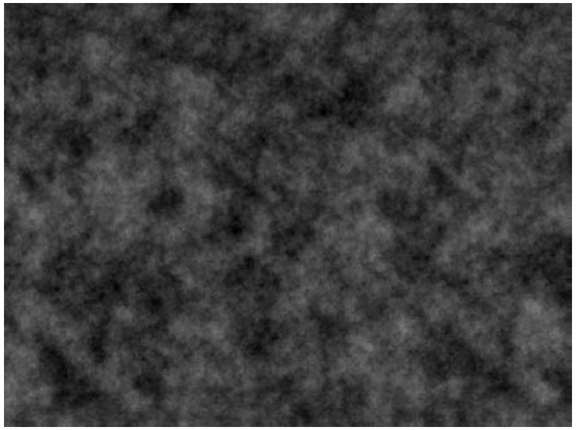
```
int octaves = 8;
float zoom = 20.0f;
float persistance = 0.5f;
float total = 0.0f;

for (int i = 0; i < octaves - 1; i++) {

float frequency = pow(2, i)/zoom;
float amplitude = pow(persistance, i);

total = total + noise(x * frequency, y * frequency) * amplitude;
}
```

Perlin Noise

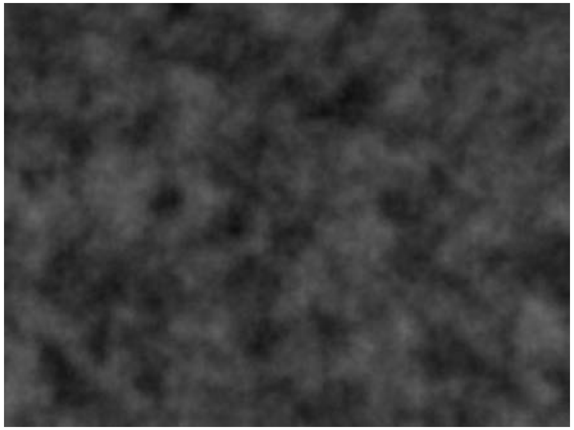




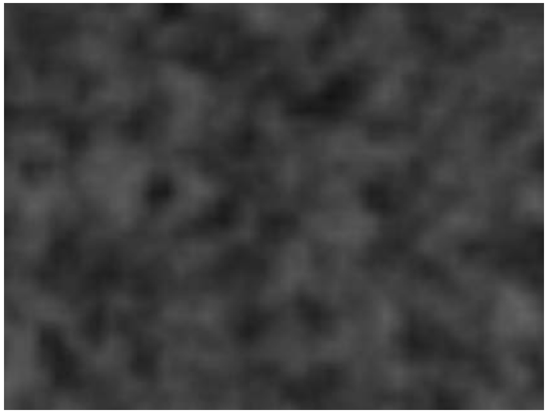
Persistance



Octave 8



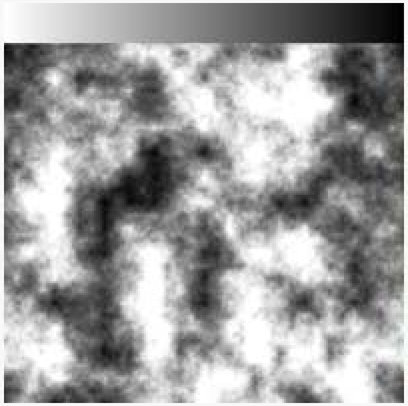
Octave 4



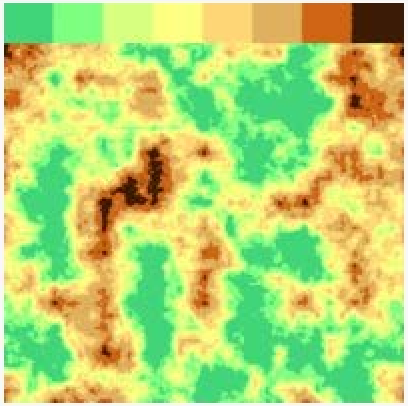
Octave 2

Applications

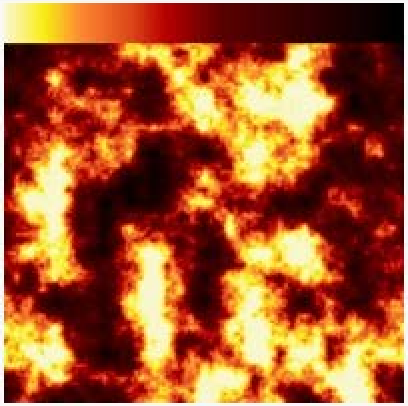
- Color Gradiant



Grayscale gradient



Gradient with discrete colours



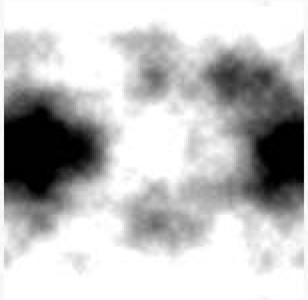
Fire gradient

Applications

- Texture Blending

Image 1

Image 2

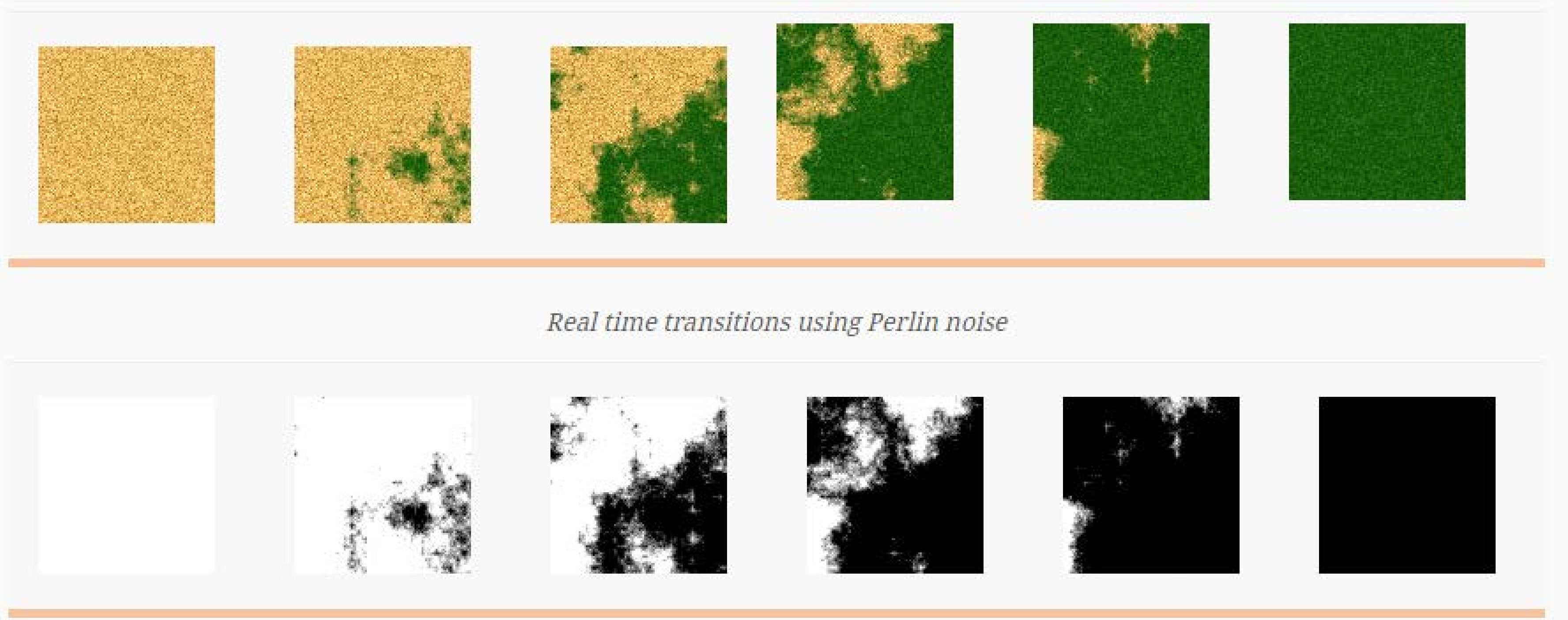


Perlin noise

Blend using noise

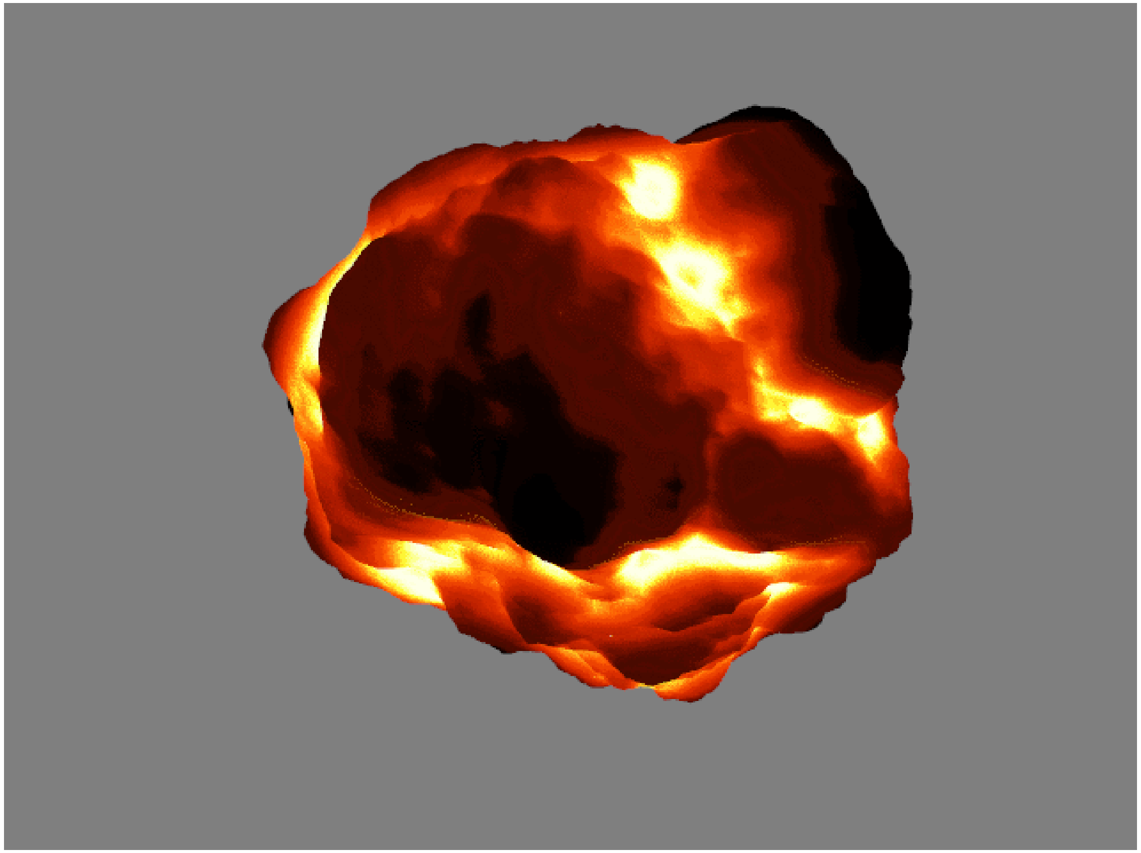
Applications

- Realtime Transition



Blend textures

3D Perlin Noise



Erosion Algorithms

- Noise alone can create interesting landscapes, but erosion can help add an extra layer of realism.
  - Thermal Erosion
  - Hydraulic Erosion
  - Inverse Thermal Erosion

Thermal Erosion

- Thermal erosion models gravity eroding cliffs that are too steep
- If the angle is too sharp, soil will fall to a lower area.
- Thermal erosion is fairly simple to model
- First, define the difference T, which is the maximum difference allowed before gravity takes over

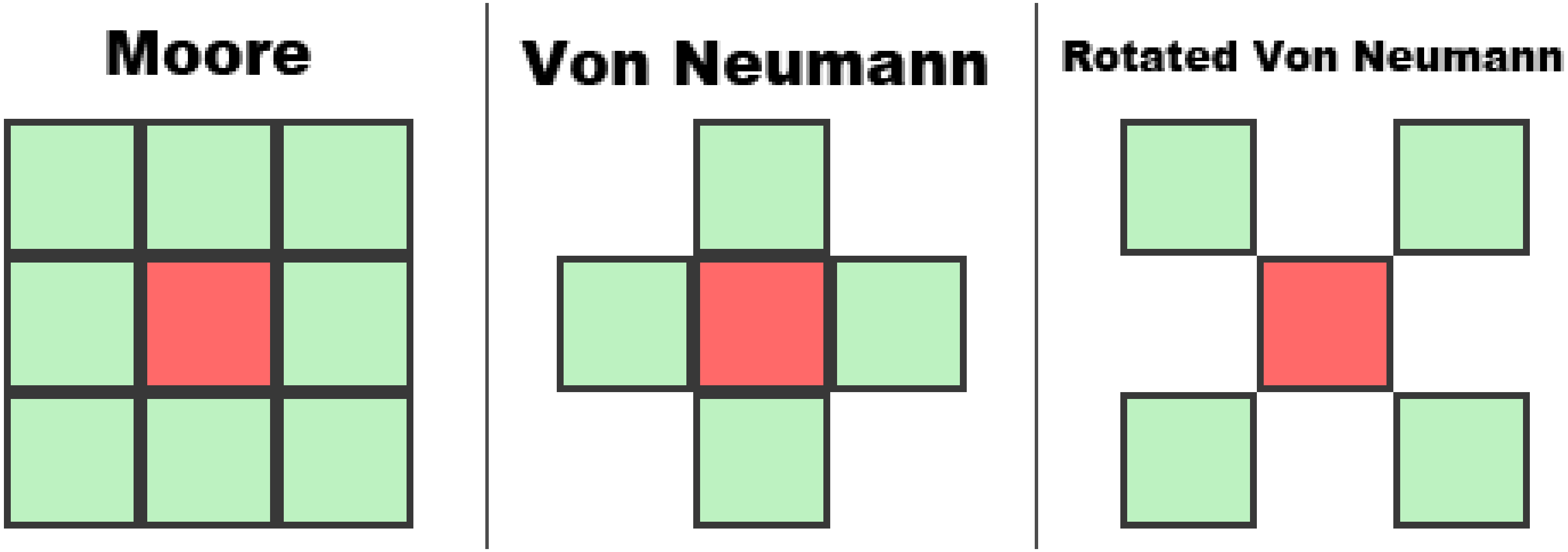
Thermal Erosion Algorithm

- For all pixel
- Get the difference in height between this pixel and the neighbouring pixel
- If the difference is greater than T, remove some amount of soil from the taller pixel and deposit it into the lower pixel.
- The speed of this algorithm can be improved further by changing the neighbourhood type.
- The three standard type are the
  - Moore neighbourhood,
  - the Von Neumann neighbourhood,
  - and the rotated Von Neumann neighbourhood

Neighbourhood Types

- In cellular automata, the Moore neighbourhood comprises the eight cells surrounding a central cell on a two-dimensional square lattice
- In cellular automata, the von Neumann neighbourhood comprises the four cells orthogonally surrounding a central cell on a two-dimensional square lattice.
- While the Moore neighborhood provides the best results, it is also the slowest. The rotated Von Neumann neighborhood gives good results while increasing speed.

Von-Neumann Neighbourhood Type



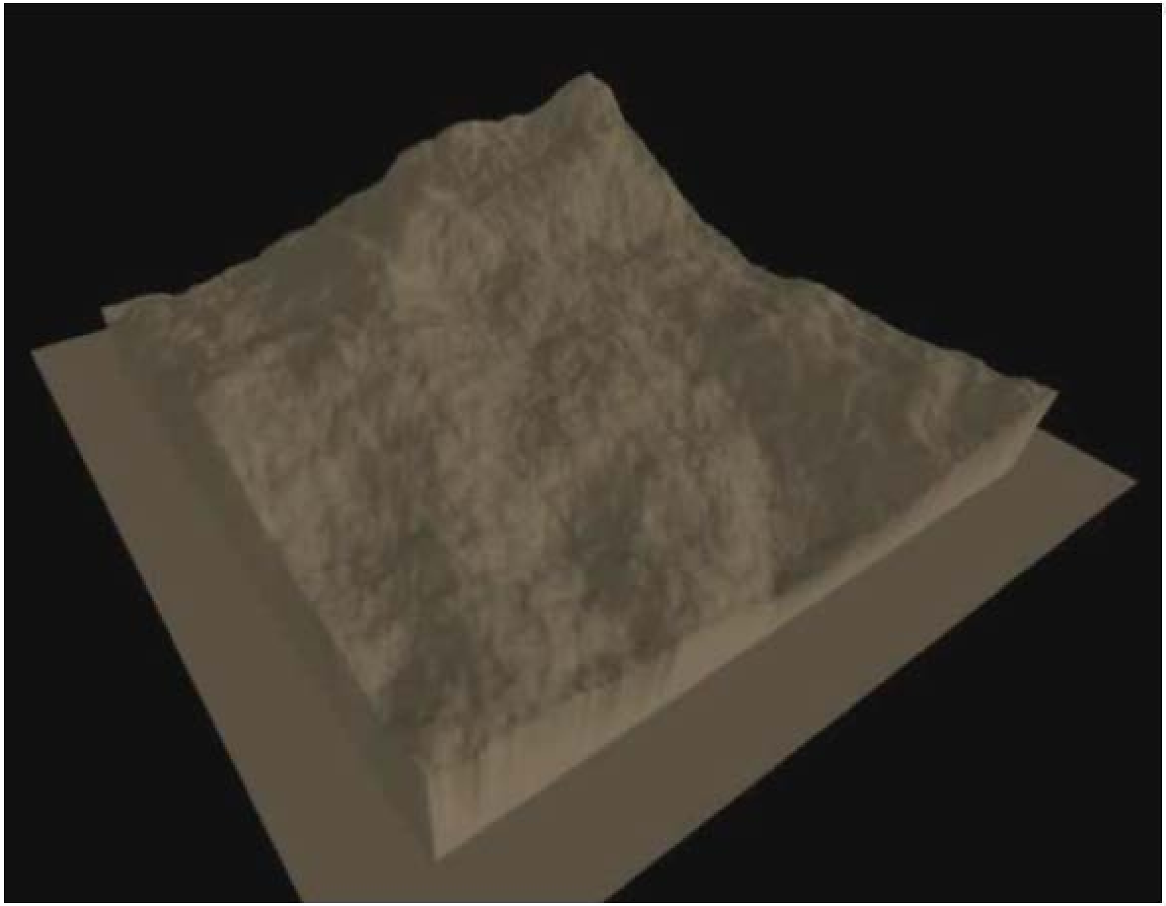
Hydraulic Erosion

- Hydraulic Erosion models rainwater picking up soil, washing down into basins, then evaporating and depositing soil.
- Hydraulic erosion provides good quality results, but is very slow.
- It may use up to 3 times the memory of Thermal Erosion.

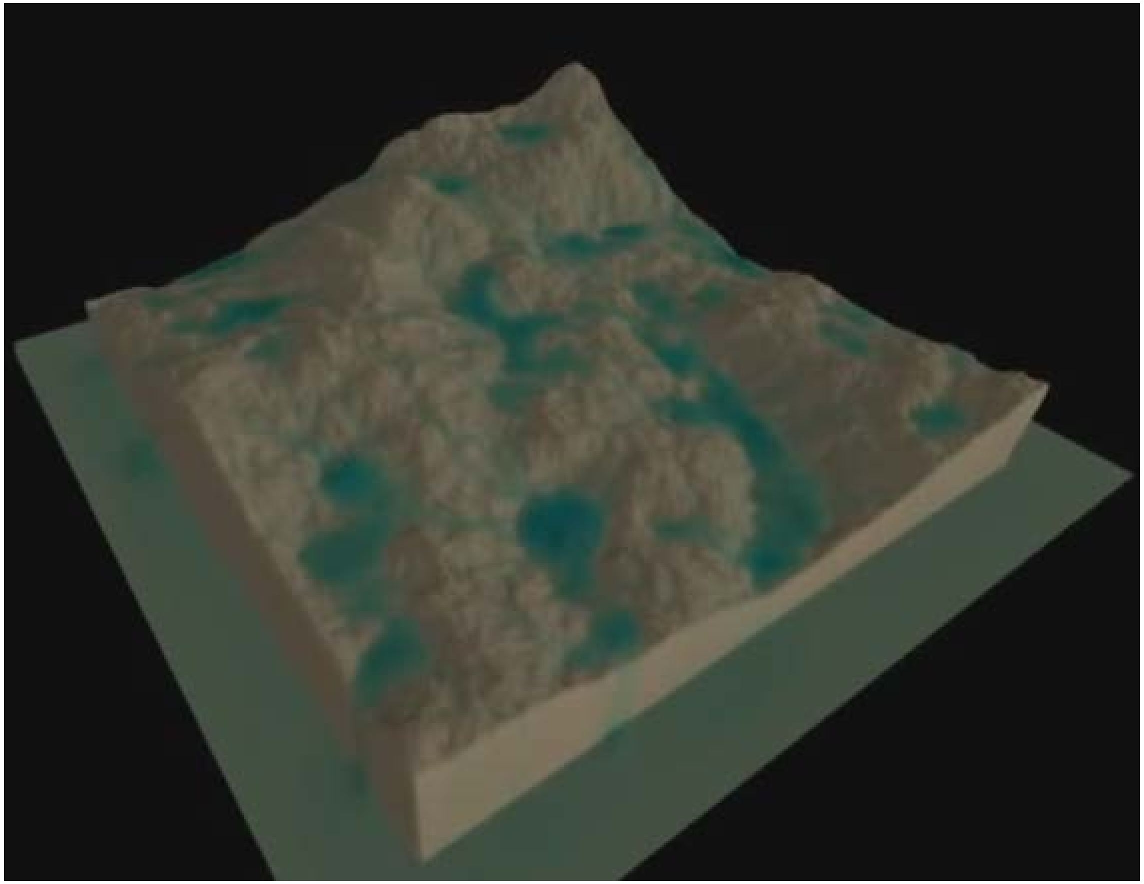
Inverse Thermal Erosion

- For gaming, plateaus and cliffs are much more desirable than rolling hills.
- Thermal Erosion destroys cliffs and rarely creates plateaus.
- By flipping the erosion condition the opposite effect can be created.

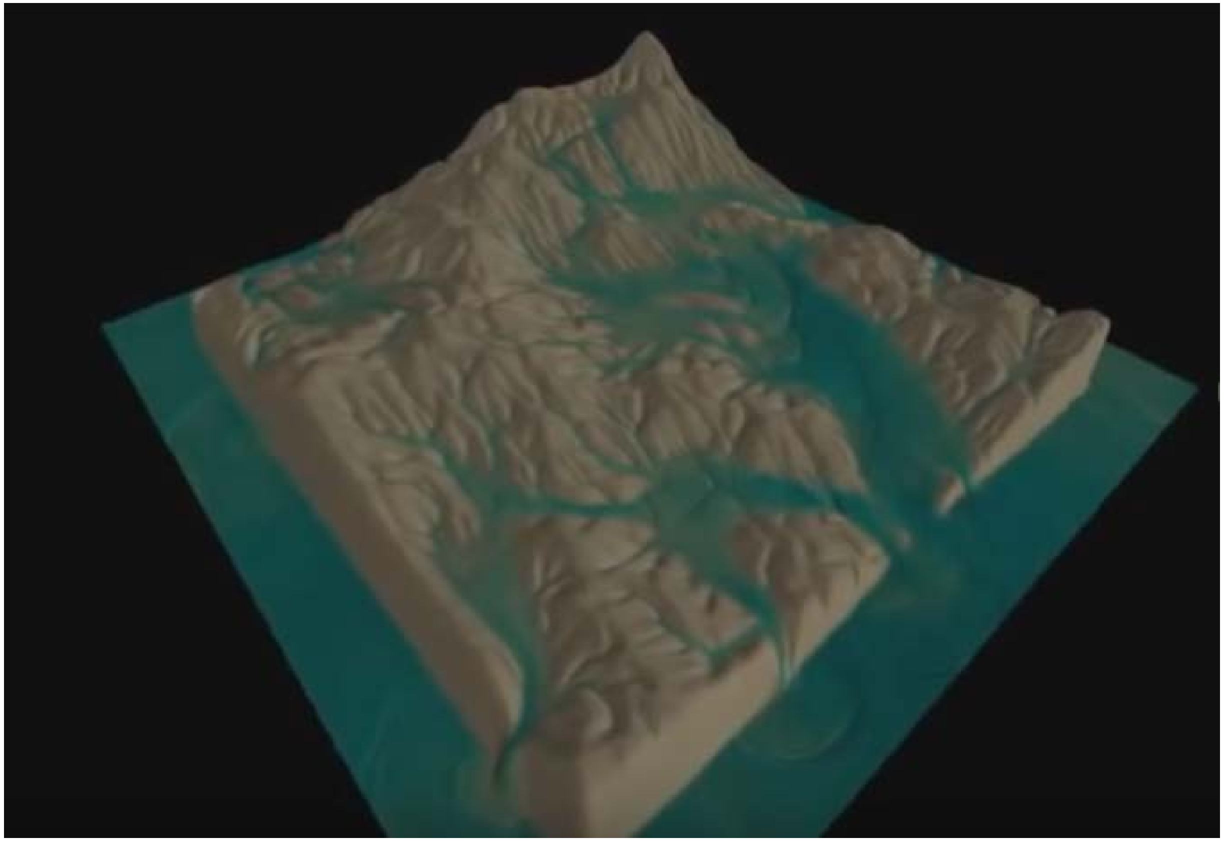
Hydraulic erosion



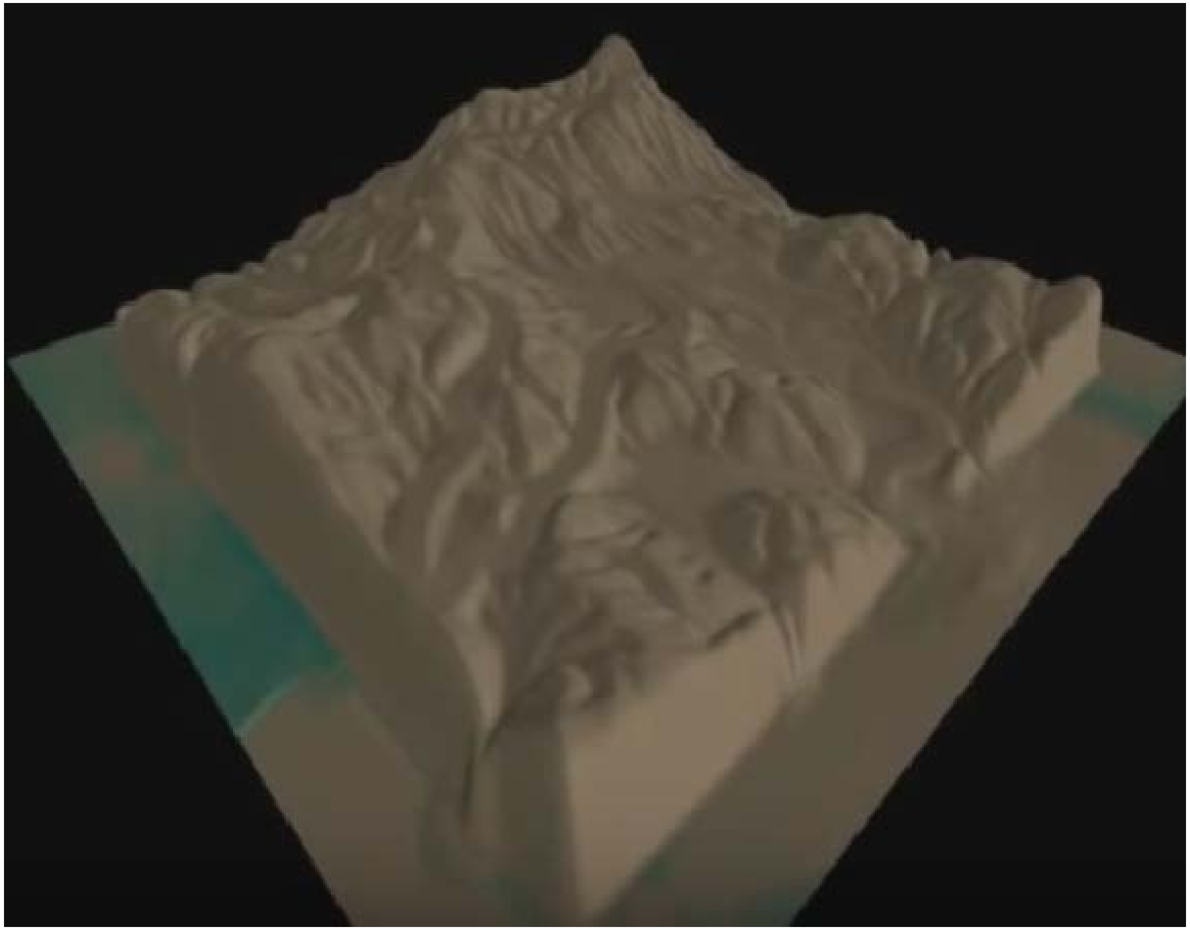
Hydraulic erosion



Hydraulic erosion



Hydraulic erosion



Vegetation Modelling

- While noise and erosion may create realistic features, without color the terrain is completely alien to the eye.
  - Simple Colour Mapping
    - Portions of height to colors or gradients of colors
  - Terrain Mandated
    - Waterflow is defined by terrain height.
    - Vegetation takes slope and height into account
  - Dynamic Modelling
    - Dynamic systems such as rainfall and water-flow could control where vegetation grows

References

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- http://flafla2.github.io/2014/08/09/perlinnoise.html
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